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THE OHIO STATE UNIVERSITY RESEARCH FOUNDATION

Report No. 6
RF Project 480

REPORT

By

THE OHIO STATE UNIVERSITY
RESEARCH FOUNDATION
COLUMBUS 10, OHIO

Cooperator AF CAMBRIDGE RESEARCH LABORATORIES
230 Albany Street, Cambridge 39, Mass.
Contract AF 19(604)-41

Investigation of FLUCTUATIONS OF STARLIGHT AND SKYLIGHT

Subject of Report Progress for the period January 1, 1953 to March 31, 1953

Submitted by J. Allen Hynek

Date May 15, 1953

ABSTRACT

In a series of simple yet elegant experiments at the telescope the essential independence of scintillation and image motion has been demonstrated. Violent image motion can result from modifying the refractive index of the air in the immediate vicinity of the telescope, but corresponding changes in scintillation fail to appear. The two phenomena are frequently not distinguished in the term 'astronomical seeing' as used in the literature.

Verification of a number of particulars in a theory of astronomical seeing recently proposed by Keller has been obtained in a series of independent experiments by Keller and Hardie at the Perkins Observatory, using an artificial star and controlled turbulence in the air path. As theory predicted, when turbulence was small the images observed in red light were sharper than those observed in blue light.

Preliminary magnetic tape recordings of stellar scintillation in daytime and nighttime were made. Calibration of the tape recorder and associated equipment proved to be a major problem.

PERSONNEL AND ADMINISTRATION

There were no changes in personnel and none in administration. In fact, there have been no changes in personnel since the inception of the project. The principle of a small, well-knit team has resulted in a high degree of staff stability.

Facilities at the University are adequate, enough space is available for the prosecution of the work, and the telescope and accessories are in good condition.

COMMUNICATIONS

A scientific report 'Astronomical Seeing and its Relation to Atmospheric Turbulence' by Dr. Geoffrey Keller was published through the Ohio State Univeristy Research Foundation and forwarded to Air Force Cambridge Research Center. This paper, a mathematical treatment of the action on starlight of disturbed layers of atmosphere, will also be issued in a larger edition by AFCRC and, in a slightly revised form, will appear in the Astronomical Journal. It has been accepted for publication in that journal after review by Dr. Chandrasekhar of the Yerkes Observatory.

On January 22, 1953, Dr. Keller and Dr. Hynek conducted a joint colloquium at the Harvard College Observatory on the subject of 'Astronomical Seeing'. The meeting was well attended by astronomers and physicists.

In February Dr. Hynek attended the Symposium on Self-Contained Navigation Systems, held at the University of California at Los Angeles. These meetings were classified. At the same time Dr. Hynek had the opportunity of spending several days at the Mt. Wilson Observatory. Discussions with Dr. Baade on studies of astronomical seeing at the Mt. Wilson and Palomar Observatories were very stimulating. The conversations were communicated to the project staff in Columbus.

Dr. Heinz Fischer, project scientist, visited in Columbus late in January to review the progress of the work.

As always, informal liaison with Dr. Hall and his co-workers at the U. S. Naval Observatory has been maintained. They have kindly kept us informed of the progress of their attempts to determine the height in the atmosphere at which scintillation sets in.

STATEMENT OF THE PROBLEM AND METHOD OF ATTACK

The central problem under attack is the behavior of the stellar image, particularly in the daytime, with the long range view of using observations of stellar image scintillation, pulsation, and movement as an upper atmosphere probe.

Clearly the first stage of this broad problem is the quantitative study of the actual behavior of the stellar image; the second is to gain insight into the physical causes of the observed behavior through laboratory experiments and theoretical studies; and finally, a systematic plan of observations must be applied to the atmosphere problem, to the problem of star trackers, and to the astronomical problem of optimum use of optical equipment for specific purposes, such as the photography of the sun and planets. It may be stated that although astronomers have had long experience with the 'seeing' problem, no real attack on understanding the problem with a view to better utilization of existing telescopes, both large and small, has ever been made. Experience has led only to empirical 'rule of thumb' methods that have been used to minimize the effects of 'seeing' in the photography of details on Mars and other planets, in spectroscopy, and in photoelectric stellar photometry.

The broad objective of this project work at the McMillin Observatory is to obtain quantitative measures of image behavior, and an understanding of its physical causes so that these may in turn be applied to optical and electronic problems, some of a military character, in guidance systems, in meteorology, and in astronomy.

To date we have concerned ourselves with only one aspect of the first portion of this threefold problem - quantitative measures on the scintillation of the stellar image. Only now are we ready to attack a second phase of this first portion, the measurement of image motion, both as to movement of the center of gravity and the variation of image diameter. The approach here is through motion-picture photography. This does not imply that the scintillation work is complete, but only that it is well enough along to allow some diversion of effort to associated problems.

The theoretical work of Dr. Keller, experiments performed by Dr. Keller and Dr. Hardie (of the Perkins Observatory) and several experiments at the McMillin telescope performed by Mr. Hosfeld represent an excursion into the second phase of the three-fold problem, the gaining of physical insight into the causes of scintillation and image motion.

It is anticipated that several years of work is yet necessary, some at other geographical locations, before the major portions of the total problem are solved. It is anticipated that the McMillin telescope and auxiliary instruments will be committed to this problem for several years.

SUMMARY OF SIGNIFICANT RESULTS OBTAINED DURING REPORT PERIOD

Systematic program observations were greatly impeded by cloudiness during the winter season. The major effort went into the laboratory program involving some specific experiments at the telescope which proved to be of considerable significance.

Mr. Hosfeld conducted these experiments and a technical report is in preparation. It will suffice here to outline the theme of the experiments.

It has frequently been asserted by some astronomers and meteorologists that the major cause of poor 'astronomical seeing' or optical damage to the image, occurs in the immediate vicinity of the telescope, and hence that stellar twinkling can hardly be used as an index of atmospheric conditions at some altitude above the surface of the earth.

That this conclusion is based on confusion as to what constitutes 'poor seeing' is clearly shown by Mr. Hosfeld's experiments.

Three commonly used criteria of seeing, i.e., image motion, image definition, and intensity variation, were observed while rather large air temperature inequalities (of the order of 30°F) were introduced into the telescope dome by admitting warm air from an adjacent hallway.

As might be anticipated on the basis of general experience at the telescope, the first two criteria were greatly affected. The definition of the moon's image was ruined and the motions of stellar images increased several fold.

The case of intensity variation, or scintillation, however, proved to be quite a different matter. No change in the scintillation of stars near the zenith was observed when warm air was admitted to the telescope dome. Neither was any change observed for stars near the horizon. No change was observed in the scintillation of an extended source area (the planet Jupiter). Finally, no change could be detected in stellar scintillation even when the telescope aperture was stopped down to a diameter of one inch.

Air temperature disturbances near the telescope were incapable of producing any detectable change in the intensity variations normally present in the stellar beam in spite of the fact that the normal image motions were increased several fold and the definition was ruined.

The intensity variations were measured by using a 1P21 multiplier phototube, an amplifier, and a Brown Recorder as described in a previous report.

The essentially total independence of image distortion and motion, and the scintillation of the image, can be reported as a striking and significant result and one that has not previously been reported in the literature.

The experiments will be described fully in Scientific Report 2 to be issued under the present program.

Experiments leading to the verification of the theory of 'astronomical seeing' recently proposed by Dr. Keller were conducted at the Perkins Observatory by Drs. Keller and Hardie. The results of these experiments will appear in Scientific Report 3 to be issued under the present program. A brief resumé of results will suffice here.

An artificial star was employed for these tests and turbulence in the air path between the artificial star and the optical system was produced under controlled conditions. Within the precision of the measurements, the experimental results were all in agreement with the theory. Notably, experiment confirmed the prediction that when seeing conditions are good (small turbulence) images observed in red light are somewhat sharper than those observed in blue light.

The Keller theory deals quantitatively with image size and the distribution of light within the image and qualitatively, as yet, with scintillation and image motion. Astronomical seeing can be defined in terms of several observational criteria which are to some extent independent of each other. That is, image steadiness, image definition, and image scintillation can be independent of each other, as Hosfeld's experiments have shown. The detailed functional relations between the three criteria above and the distribution of intensity within the image, the principal concern of the Keller theory, should prove an interesting problem.

It will be of particular interest, in view of the demonstrated independence of scintillation and image motion, to establish with which of these two criteria of seeing the turbulence that produces change in image intensity distribution is correlated.

Studies in the harmonic analysis of stellar scintillation were seriously delayed by difficulties which developed in the operation of the magnetic tape recorder.

The tape recorder method is without question an ideal manner in which to record stellar scintillations, provided that fidelity of recording and transcription can be had.

During the process of calibration of the tape recorder and associated equipment, it was discovered that the output of the recorder was erratic. Considerable instrumental noise of an unpredictable nature was apparently being introduced by the recorder itself.

Numerous minor changes in circuitry and in manner of operation were made. For instance, high frequency signals from the multivibrator used in the recorder circuitry were being pulsed up by the preamplifier when high imput impedances were used. This was sufficient to drive the preamplifier to cutoff when signals which it could normally handle were applied.

The noise which now remains in the system appears to be only that associated with the tape transport mechanism. However, successful preliminary recordings on tape of a star in both daytime and nighttime have been made.

Calibration and testing of the magnetic tape mechanism continue to occupy the major portion of Mr. Protheroe's time.

FUTURE WORK

Mr. Hosfeld will continue the preparation of his paper on the independence of image motion and scintillation. He will also extend his efforts to the photographic study of image motion and distortion. Measures of gross scintillation of stars (integrated effect of frequencies below 10 cps) in the daytime to provide continuity of record will be continued.

Mr. Protheroe hopes that the many instrumental difficulties which beset him in the 'automatic' recording of daytime stellar scintillation will be conquered. These difficulties are of major concern because the phenomenon under observation is a threshold one, particularly in the daytime case where one is literally 'picking a signal out of the blue'.

If and when instrumental difficulties are overcome, harmonic analysis of considerably more detail than before will become possible.

NOTE: In submitting this report it is understood that all provisions of the contract between The Foundation and the Cooperator and pertaining to publicity of subject matter will be rigidly observed.

Investigator ..... Date .....

Supervisor J. Allen Hynek Date May 29, 1953

For The Ohio State University Research Foundation

Executive Director Ivan C. Wright RJH Date 6/1/53

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AIR FORCE RESEARCH LABORATORY (AFMC)

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SUBJECT: Distribution Statement Change

1. The following documents have been reviewed and it has been determined that the distribution statement is no longer appropriate. The documents are Progress Reports 1 through 8 under Contract No. AF19(604)-41, Ohio State University Research Foundation, Columbus, OH.

a. Document No.: AD 000014
Title: Fluctuations of Starlight and Skylight
Date: 15 Mar 1952
Classification: Unclassified

b. Document No.: AD 000027
Title: Fluctuations of Starlight and Skylight
Date: 15 Apr 1952
Classification: Unclassified

c. Document No.: AD 000066
Title: Fluctuations of Starlight and Skylight
Date: 25 Jul 1952
Classification: Unclassified

d. Document No.: AD 005282
Title: Fluctuations of Starlight and Skylight
Date: 1 Nov 1952
Classification: Unclassified

e. Document No.: AD 010919
Title: Fluctuations of Starlight and Skylight
Date: 24 Feb 1953
Classification: Unclassified

f. Document No.: AD 021921
Title: Fluctuations of Starlight and Skylight
Date: 15 May 1953
Classification: Unclassified

g. Document No.: AD 021922
Title: Fluctuations of Starlight and Skylight
Date: 25 Jul 1953
Classification: Unclassified

h. Document No.: AD027024
Title: Fluctuations of Starlight and Skylight
Date: 23 Nov 1953
Classification: Unclassified

2. Request these documents be assigned Distribution "A" Statement. These documents have been reviewed and cleared for public release by ESC/PA.

3. This action is in response to FOIA 2000-33.

Noreen Dimond

NOREEN DIMOND
STINFO OFFICER

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